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Physiological and chemical studies upon the milkweed (*Asclepias syriaca* L)

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PHYSIOLOGICAL AND CHEMICAL STUDIES UPON THE
MILKWEED (Asclepias syriaca L.)

BY

Fisk Gerhardt

A Thesis Submitted to the Graduate Faculty
for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject Plant Physiology

Approved:

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In charge of Major work

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Iowa State College

1928

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INTRODUCTION

The milkweed plant, Asclepias syriaca L. like the Jerusalem artichoke, Helianthus tuberosus L. and possibly the sunflower, Helianthus annuus L. belongs to a group of plants possessing some potential economic value. Though this plant is generously distributed throughout the United States and Canada, and has received a certain amount of scientific attention in the past, only plants grown in their native habitat have been used in securing the data. The plant parts which lend themselves to possible commercial utilization are the seed, with its high content of protein and oil, the silvery white seed coma, the latex with its rubber content, and finally the long bast fibers of the stem tissue. Interest in the possibilities of this plant has been aroused from time to time especially from the standpoint of rubber production. It is true that the quality and quantity of rubber has been found to be low, however, none of the other possible uses of the plant have received adequate attention. It was therefore deemed advisable to make a rather intensive investigation of a number of products as they are found in the milkweed plant when under cultivation.

The following study was undertaken with the cognizance that the most progress could be made in determining the potential value of the milkweed plant only through a study of the

entire plant and a number of its products. With this thought in mind, methods of plant propagation, cultural practices and crop yields, under experimental conditions, received our consideration as it is recognized that plant response in its natural habitat may be quite different from that under cultivated conditions. In order to adequately accomplish the above task it also became obligatory to follow the various food translocation changes in the plant from germination to maturation.

DESCRIPTION AND DISTRIBUTION

The common milkweed (Asclepias syriaca L.) according to Britton and Brown belongs to that group of perennial herbs, vines or shrubs with a milky juice comprising the Asclepiadaceae family. The genus Asclepias is composed of more than eighty members of which the species Syriaca is probably the best known. This perennial plant grows from 3 to 6 feet high and possesses large thick opposite leaves with a minutely downy under surface. The plant makes its appearance in May, produces many flowered purple umbels during the latter part of June or fore part of July. After fertilization, the enlarged carpel produces the characteristic pod. The thin cartilaginous seed incases a mass of silvery white coma. In the late fall the pods open, thereby enabling the contents to be disseminated by wind and insects.

The common milkweed occupies diverse habitats throughout the United States, from Maine through southern Canada and the central and western states as far south as North Carolina and Kansas. It may be found in pastures, cultivated fields and waste places. It is not specific as to the type or fertility of the soil medium. The necessary cross-fertilization of the flower is aided by insect and by wind; seed dissemination over vast distances is enhanced by birds as well as

* Reference is made by number to "Literature Cited."

by small tufts of floss attached to each seed. These advantages coupled with an admirably developed root system have insured the milkweed plant a wide distribution and a tenaceous, prolific growth, once established.

HISTORICAL

Some scientific interest, other than that, of a taxonomic nature, has been manifested in Asclepias syriaca L. for many years. As early as 1862 Meitzen reported upon his attempts to utilize the seed coma of Asclepias as a textile material. He found the fibers straight, brittle and unsuited as a source of fabric material.

Most of the earlier investigations of this plant were undertaken from the point of view of its being a possible new source of rubber. Saunders as early as 1875 called attention to the presence of rubber in the latex of the milkweed. By means of fermentation, prior to extractions, he claimed to have produced a superior quantity of rubber. George Kassner, Breslau, Germany in 1886 secured English patent rights on improvements in the process or manner of manufacturing caoutchouc, wax, fat, vegetable fibre, etc. from lactucarious plants. The first serious consideration of the yield, quantity and value of the rubber present in the milkweed, grown under natural conditions, was presented by Fox. He found the latex to be milk-like, thin, acid or neutral in reaction, with a characteristic milkweed odor. It was not coagulable by heat, ammonia or alcohol, yielding rubber on the basis of latex from two to three per cent. The caoutchouc obtained was flabby, lacked strength and firmness. Fox concluded "that the amount of rubber was so small, its quality so inferior and its cost of production so high that

from the standpoint of rubber production alone, the milkweed plant had little commercial value."

(18)

Neish in a preliminary survey has called attention to the possible value of certain by-products of this plant such as seed fibers, bast fibers, oil and protein possibilities from the seed, together with a few remarks pertaining to the use of this plant as a source of paper stock. Marsh and Clawson have reported the presence of one poisonous species within the milkweed family, which when eaten by animals produced trembling, with death following by violent spasms and respiratory paralysis. Two glucosides were isolated, both producing extreme narcosis. The powdered roots of the milkweed have been used in medicine as an emetic and cathartic.

(10)

During the world war, Hall and Long, made an extensive rubber survey of the various species of milkweed found in the United States. Their report consisted of a description of each plant together with percentages of rubber and resin found. These studies were conducted upon native plants, and their report indicated that before any definite recommendations could be made upon the merits of the milkweed, it should be given the attention such as is demanded of our cultivated crops.

The laticiferous system in certain families of the Angiosperms has long remained an interesting field for physiological and histological investigation. The work of Schullerus, Molisch, Weiss and Wiesner, Haberlandt, Boussingault and Parkin has thrown considerable light upon the structure and composition

(27)

(16)

(30)

(9)

(1)

(20)

of these highly specified organs. From a morphological standpoint it became mandatory to distinguish between two different types of laticiferous systems, namely, articulated latex-tubes (25) or vessels and non-articulated latex-cells. The former are formed from rows of longitudinal cells within the meristematic tissue in which the transverse septa become dissolved at an early period. The articulated system is characteristic of the Chicoriaceae, Campanulaceae, Papaveraceae, Araceae and of the genera Manihot and Hevea among the Euphorbiaceae.

The latex-cells comprising the non-articulated system are found in the majority of the Euphorbiaceae, Urticaceae, Apocynaceae and Asclepiadaceae. Chauveand's observations have shown that the initial latex-cells in the latter system are recognizable even in the young embryo of the Euphorbiaceae and arise from single cells located in the primary cortical tissue. These cells become enormously elongated and ramified, forming a network throughout the plant tissue. According to Treub, the (29) cells comprising the laticiferous system differ from most vegetative structures in that the former are multinucleated. The latex-cells are not formed during the growth of new tissue, the entire laticiferous structure originates from a few mother cells which are located in the embryo. (11) Holmes has reported the presence of a flagellate Herpetomonas elmassiani (Migone) in the latex of Asclepias syriaca L. It may be present, however, in very large numbers without appearing to interfere with the

normal growth of the plant or to produce visible modification of the various tissues. The fact that there is no continuity between the individual latex-cells in the laticiferous system of the common milkweed, offers a rational explanation for the difficulty experienced in the collection of suitable amounts of latex for experimental purposes.

Since the fruit of the Asclepias produces an abundance of white coma, the use of this material as a source of textile fiber has received considerable interest in the past. A review of textile literature has shown these fibers to be entirely unsuited for spinning or weaving. Dischendorfer, after a careful study of these fibers, found a high content of lignin and inorganic constituents present. The cell walls were shown to be exceedingly thin, and irregular, with the fibers, as a whole possessing little strength or elasticity. Mathews, in his description of Asclepias floss has disclosed the fact that this material, although possessing a beautiful silky appearance, is unsuited for the manufacture of textiles. The fiber is quite brittle in nature, possessing little tensile strength. Its chief physical quality is its high degree of luster and softness. No report, however, has been found relative to the usefulness of this material in the bedding or upholstering industry.

EXPERIMENTAL PROCEDURE

Source of Experimental Material

From the literature presented, it is evident that practically all the recorded experimentation has been made upon wild plants. In the following studies it became paramount from the beginning, that attention should be focused toward means of propagation and development of Asclepias syriaca L., and that the physical and chemical studies should be conducted upon cultivated plants. With this thought in mind, a normal, healthy patch of common milkweed was sought in order to serve as a source for experimental material. Such an area of native plants was found along a road side two miles south of Ames, Iowa. This plot, comprising an area of approximately eight hundred square feet, represented the foundation stock for propagation by seed and by root cuttings.

PREPARATION OF MATERIAL FOR ANALYSIS

Investigation of certain food reserves in the milkweed plant necessitated the collection of various plant parts at stated intervals. These samples, immediately following collection, were brought to the laboratory, cut into one inch pieces and placed in a Freis electric oven, being desiccated at 65° C. in a current of air. The dried tissue remained a deep green in color, indicating that proteolytic as well as hydrolytic changes remained practically negligible. Chemical analyses were made upon this material using the various methods and technique cited below. The air-dried material was ground through an "Empire" and "Merker" mill respectively, until the ground product could be passed through a 100 mesh sieve.

Methods of Chemical Analysis

Moisture Determination:- A tared sample of ground tissue was dried to constant weight in a Freis electric vacuum oven at 70° C.

Fat:- The residue from the moisture determination was freed from lipoids and soluble pigments by percolation with anhydrous alcohol-free ether. The ethereal extract was dried to a constant weight in an electric oven at 100° C. and expressed as percentage fat.

Reducing Sugars:- After expulsion of the ether, the residue of the sample was extracted with boiling 90 per cent

alcohol (to which a small amount of CaCO_3 was added) for one-half hour on a hot plate. The filtered extract was concentrated for alcohol removal, diluted with water, clarified with neutral lead ^{acetate}, freed from excess lead by sodium carbonate and finally made up to definite volume. Reducing sugars were determined by the Quisumbing and Thomas method and expressed as per cent dextrose. (22)

Total Reducing Sugars:- Aliquot portions from the original sugar extract were hydrolyzed with 2.5 per cent HCl for one hour. Total reducing sugar determination and expression of results are identical to those used for simple reducing sugars.

Starch and Dextrin:- The residue from the sugar extraction was boiled with 150 cc. of water for two minutes in order to gelatinize the starch. After cooling to 38°C . and digesting with fresh saliva until a negative result was obtained with iodine, the filtered solution was hydrolyzed with 2.5 per cent HCl for 2.5 hours. Glucose was determined by the above mentioned method, multiplied by the equivalent value for starch and dextrin, and expressed as per cent starch. This figure actually includes the amount of water soluble pentosans and any other soluble or partially hydrolyzed products possessing reducing power.

Hemicellulose or Acid Hydrolyzable Material:- The residue from starch digestion was boiled with 150 cc. of 2.5 per cent H_2SO_4 (by weight) for one hour. The filtered solution was

neutralized and clarified in the usual manner. The reducing power of this group of carbohydrates was determined by the Quisumbing and Thomas method and expressed in terms of glucose.

Ash:- A two gram sample was ashed at a low temperature in an electric furnace to a constant weight.

Pentose:- Two gram samples were distilled with 12 per cent (19) HCl according to the Official Methods. The furfural phloroglucid value was multiplied by the proper equivalent and expressed as percentage pentose.

Total Nitrogen as Protein:- The total nitrogen present in a two gram sample was determined by the Kjeldahl method multiplied by the factor 6.25 and represents the total nitrogen expressed as crude protein.

Acetone Extract:- A two gram sample was extracted twenty-four hours on an electric hot plate with C. P. acetone. The weight of the evaporated extract, containing gums, resins, and pigmented material was expressed as percentage acetone extract.

Benzene Extract:- The residue from the acetone removal was extracted twenty-four hours on an electric hot plate with C. P. benzene. The soluble product (rubber) was expressed as per cent benzene extract.

In the presentation of the chemical data, all percentages are calculated upon an air-dry basis.

EXPERIMENTAL RESULTS

Means and Methods of Propagation

The two general methods of propagation involve development through vegetative or sexual means. In the successive reproduction of many plants, the former has displaced the latter. Probably the time factor has been one of the more important considerations. Realizing that the milkweed is a perennial, attention was first given to the vegetative method of development.

As previously mentioned, the native plot of common milkweeds, during the fall of 1925, served as a source for experimental material. It should be noted at this time that the milkweed has an exceedingly large and ramified root system. Diggings have shown these roots to penetrate the sub-soil nearly six feet, with smaller roots branching horizontally at various depths. There is usually present a well developed root system parallel to, and about six inches beneath the soil surface. Adventitious root buds along the surface of these roots are continually producing new stem and leaf tissue. Observations have shown the vegetative viability of the older root stocks to approximate three years.

Root propagations made upon the following dates of October 3, November 5, December 4, and January 10, were taken to a greenhouse having a medium temperature. The roots were placed in seven gallon earthenware jars, where one-half of the plants were

set in a sand medium and the remainder in clay loam. In the October root collections, it took a period of six weeks before growth was induced, while in the subsequent propagations the time interval became proportionately less, until the January plantings required only two weeks. The treatment as presented here points toward a well defined rest period. No attempt was made to shorten the rest period by use of chemical reagents. In all cases the sand cultures were superior to those in the clay loam medium. In both series the amount of stored food material of the roots was very much the same; the only explanation for the greater response in the sand cultures was due possibly to a better aeration of this medium. Normal growth of these plants, however, was not attained in the greenhouse, and when transplanted to an out-of-door plot in the spring, they were no farther advanced, after a few weeks, than those which came up under normal environmental conditions. The greenhouse procedures offered little encouragement as far as enhanced development was concerned. Since the roots of the common milkweed undergo a definite period of rest, vegetative propagations then could effectively be made without loss of an appreciable amount of time from roots which had been allowed to remain out of doors all winter.

Attention was next directed toward methods of propagation by seed, involving germination studies. (Seed was collected, prior to a killing frost, from native plants grown during the

summer of 1925. The seed when placed in germinating chambers did not show active germination until they had been stored in the laboratory for a period of approximately three months. This indicates that milkweed seed must pass through a rather protracted period of after ripening. The importance of delayed germination was substantiated by the fact that seeds allowed to remain in the pod over winter gave a decidedly higher percentage of growth as compared with tests shortly after maturity. It was further shown that scarification following immediate collection in the fall did not materially enhance growth.

Following an after ripening period of three months, a number of methods were utilized for the purpose of ascertaining the kind of practice necessary to attain a maximum percentage germination. A summary of the data obtained is presented in Table 1.

A study of Table 1 reveals several interesting facts. Untreated milkweed seeds have a low percentage of viability. Germination is slightly increased by subjection to a lower temperature. Various chemicals, such as ethyl ether, chlorohydrin, carbon tetrachloride and phenol, regarded as plant stimulants, actually in several cases hinder germination. Ultra-violet rays gave a response only slightly above that of untreated seeds. Unlike the cat-tail, the milkweed fails to germinate under partial oxygen pressures. Whenever an abrasion of the seed coat is induced, either by concentrated H_2SO_4 or by physical scarification, a decidedly higher germination results.

Table I.

The Effect of Seed Treatment upon Germination of Milkweed Seed

Seed Treatment	Germination	Embryo tip of previous-ly treated seed clipped % Germination
(Temperature Effect)		
1 - Untreated Room Temperature:	21	90
2 - Untreated 10° C. - 5 days	29	92
(Effect of Chemicals)		
3 - Ethyl Ether fumes - 6 hrs.:	20	80
4 - " " " - 16 hrs.:	15	68
5 - Chlorohydrin, soak 5 hrs.:	None	None
6 - Chlorohydrin fumes-10 hrs.:	12	86
9 - Carbon tetrachloride fumes - 16 hrs.:	12	93
10- Ethyl Bromide fumes-5 hrs.:	20	92
11- " " " -16 "	25	92
12 - Phenol fumes - 16 hrs.:	16	88
13-Ultra violet light-10"daily:	32	88
14 - Conc. H ₂ SO ₄ - 3 min.:	40	92
15 - " " 6 "	52	92
(Effect of Seed Coat Abrasion)		
16 - Scarified - Room temp.:	80	90
17 - Scarified - 10° C.5 days	95	95
(Effect of Partial Oxygen Pressure		
18 - Untreated (Under water)	None	None
19 - Scarified (Under water)	None	None

This fact is further substantiated by the increased response noted for the same seed in column three of the above table. The hard, exceedingly impervious seed coat when ruptured probably permits the normal physical process of imbibition to proceed, resulting in an increased germination. These data tend to indicate that it is the physico-chemical nature of the seed coat during the breaking of the rest period which largely controls successful germination.

The desirability of establishing an experimental plot to study cultural responses, growth, yield, and food translocation has been previously noted. During the fall of 1925 a quart of seed was collected from plants growing under natural conditions. These were dried in paper bags in the laboratory; scarified samples gave an average germination of 85 per cent the following spring.

During the week of May 1, 1926, one pint of seed was placed into a small sandpaper lined box 6 inches square and scarified with the aid of compressed air playing upon the sides of the box. About one-twentieth of an acre was utilized in the planting of scarified seed in rows three feet apart. Due to excessive drought, germination was slow; the young plants attained a height of five inches by June 15. The plot at this period required severe thinning.

The common milkweed, being a perennial, attained an average height of about 40 inches at the end of the first year. A

marked difference in size and luxuriousness of growth was noted in the various plants. Five plants of the entire plot manifested the unmistakable signs of being annual strains, by blossoming and producing seed the first year. These were noted and the seed collected separately the following year. A severe killing frost during the first week of October 1926, resulted in the shedding of all leaves and cessation of further growth and development. The abundance of seasonal root formation is shown in Plate 1.

In the spring of 1927 active growth of the milkweed plants in the plot, as manifested by their appearance above ground, began early in May. The condition and mode of formation of new plants can be seen in Plate 2. An abundance of adventitious root buds are shown appearing from the surface of the previous year's root stocks. This plate would indicate that by cultivation and breaking of these older root stocks, the distribution of the common milkweed may actually be enhanced instead of curtailed. This observation is partially substantiated by the numerous unsatisfactory results obtained during the attempted eradication of the common milkweed from cultivated areas. ✓

During the fore part of July, the entire growth of the experimental plot attained the full blossom stage in its development. The large purple umbels were exceedingly beautiful and fragrant, attracting the honey bees to the extent that the entire plot became a veritable bee hive. Plate 3 is a picture

of this plot, taken July 10 during the late blossom stage. The umbel or blossom cluster is possessed of a large number of individual flowers. ⁽⁸⁾ Gager has called attention to the interesting and curious modification of flower structure in the milkweed family. Only an exceedingly small number, possibly three or four, of the flowers in each umbel are fertilized, after which the carpels increase enormously in size and develop into the characteristic milkweed pod.

Since there were five plants noted at the end of the previous year's growth which were clearly characterized as annuals, an attempt was made to self-pollinate them. In some cases each separate umbel upon the plant was covered with a transparent Glassene bag, in others several umbels of the same plant were enclosed within one bag. In no case, however, was there a successful fertilization as manifested by pod formation. These preliminary results would tend to indicate that successful enlargement of the carpel is dependent upon cross-fertilization wherein the importance of wind and of insects plays a major role.

Harvest and Crop Yield

The plants growing under cultivated conditions attained maturity during the fore part of October. The harvesting of the seed and floss was greatly facilitated through gathering of the fruit prior to its bursting. The pods were snapped from the stalk and gathered in baskets, with a total yield

amounting to approximately nine bushels. The collected material was spread over considerable floor space and allowed to dry at room temperatures for three weeks. During this interval the process of desiccation was manifested by the liberation of masses of coma.

The stems remaining upon the plot were cut, tied into bundles, and shocked subsequent to removal and storage in a dry room for future fiber and paper investigations. Plate 4 shows these stems while standing in the shock. The total air-dry weight of this material amounted to 90 pounds for the one-twentieth acre plot, yielding at this rate approximately nine-tenths of a ton of dry stalks per acre.

An ordinary "Eagle" cotton gin secured from the Continental Gin Company, Birmingham, Alabama, having 10-inch saws, operating either by hand or electric power was used in separating the seed from its floss. Considerable difficulty was experienced in this process, due chiefly to brittleness and lack of adherence of the seed fibers. It became necessary to make a small modification in the saw guides of the gin to facilitate the retention of the light, thin milkweed seed. The yield of clean seed from the experimental plot amounted to 2.5 pecks (0.62 bushel) or 12.5 pounds. The yield per acre at this rate would approximate 12.5 bushels. A bushel of milkweed seed will weigh between 20 and 25 pounds, depending upon the environment and luxuriance of growth. The weight of the bulky coma or floss amounted to only

five pounds, with an acre yield at this rate of one hundred pounds.

The yields from the cultivated plot were apparently low, due to excessive crowding of the plants within each row, and the subsequent keen competitive growth relations. The effect of this condition upon pod formation is shown in Plate 5. There probably would have been a more luxuriant growth response, had the plants been placed in hills a foot apart.

A theoretical yield per acre for this plant can be approximated by assuming first, that one plant per square foot is adequate for normal growth; second, that growth response for the cultivated and native grown plants would remain equal. If such a condition were granted, it should be noted that one milkweed pod averages 170 seeds, and weighs one gram. With ten pods per plant, there is an average production of ten grams of seed. An acre containing 45,560 square feet would produce 965 pounds or about 48 bushels of seed per acre. The average yield of seed floss per plant is five grams, following the above calculation, an acre should produce approximately 480 pounds of seed fiber. The actual yield of seed and fiber from the experimental plot amounted to about one-fourth of this theoretical quantity.

Food Translocation in the Plant

In order to gain definite information relative to the various chemical transformations which might affect growth, it be-

came necessary to make a chemical study of the plant at various stages in its development. The experimental plot again remained the source for this material. Root samples were collected once a month beginning November 1926 to November 1927, inclusive. Samples of the green portion of the plant were collected at stated intervals from May 1927 to November 1927, inclusive. The plants succumbed to a killing frost the fore part of October, therefore, the November sampling was indicative of post-mortem composition.

The data pertaining to the chemical composition of the leaves will be found in Table 2 and shown graphically in Figure 1. Young milkweed leaves are high in nitrogen, reducing and total sugars. During the normal development of the plant, the leaves are subjected to a heavy drain of these food reserves, losing over 70 per cent of their nitrogenous constituents and more than 80 per cent of their soluble carbohydrates. Fat, ash and rubber are present in increasing amounts with the development of the plant. Gums, resins, pentosan and hemicellulose material represent the more insoluble reserves, exerting probably a minor influence upon metabolism as shown by their constant composition irrespective of the age of the leaf. It is interesting to note that there was no starch present in the leaves, since the gelatinized water extract gave a negative iodine test. Rubber (benzene extract) increases with the age of the plant. A post-mortem examination, however, as

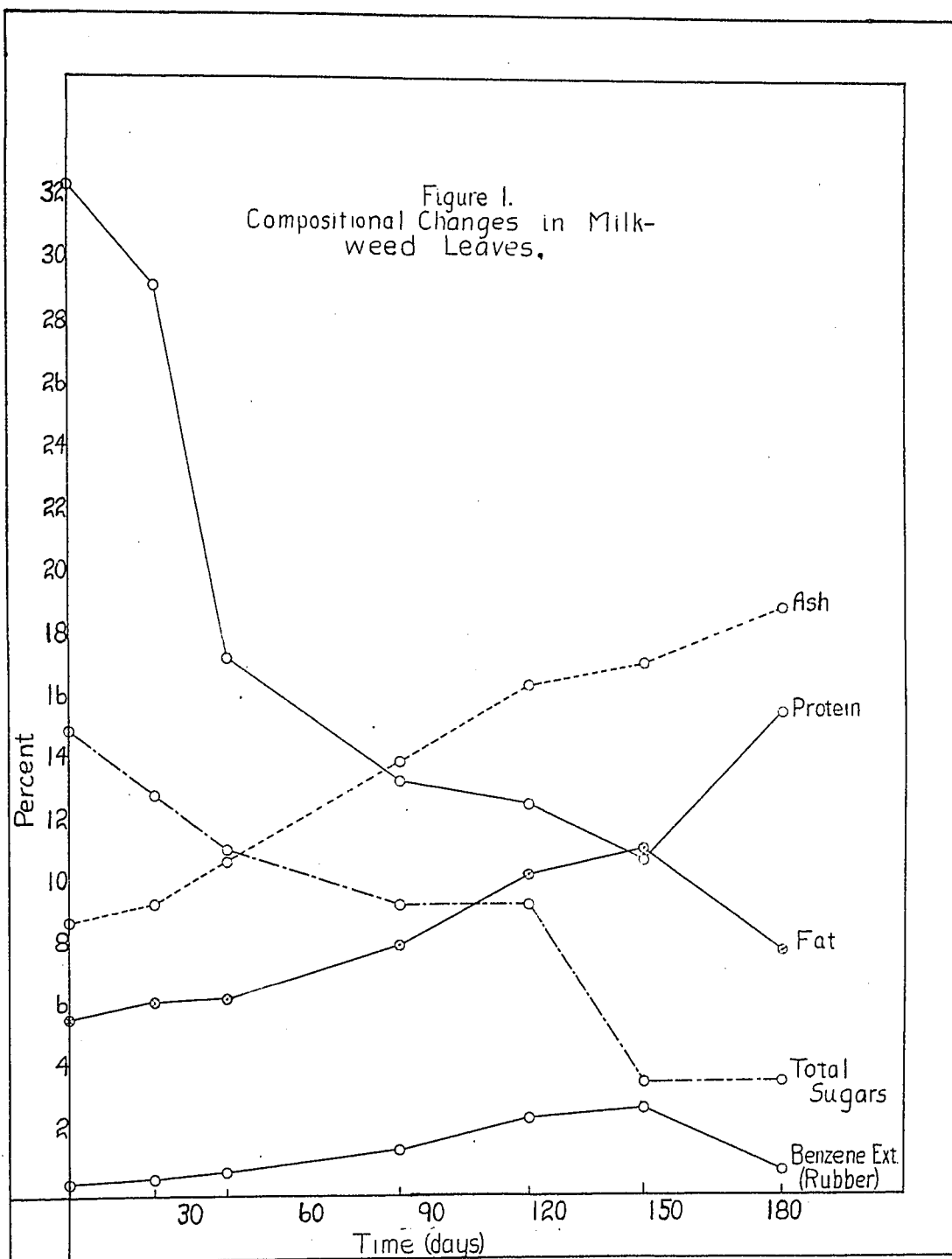


Table II

SHOWING COMPOSITION OF MILKWEED LEAVES DURING GROWTH CYCLE

Sample	Moisture	Total Nitrogen as Protein	Ash	Acetone Extract	Benzene Extract
May 15	2.58	32.55	8.90	14.45	0.49
June 5	2.20	29.39	9.50	13.75	0.60
June 23	2.75	17.50	10.90	15.00	0.81
Aug. 5	3.50	13.45	14.10	13.45	1.50
Sept. 7	2.30	12.77	16.60	14.68	2.55
Oct. 6	2.50	10.93	17.30	12.98	2.85
Nov. 10	2.35	15.75	19.10	11.20	0.82

Table III

CHEMICAL COMPOSITION OF MILKWEED STEMS

May 15	2.26	23.50	8.45	22.70	0.30
June 5	3.72	15.05	7.00	25.60	0.27
June 23	3.18	9.72	5.15	20.25	0.47
Aug. 5	3.45	6.56	2.80	18.30	0.40
Sept. 7	2.85	5.05	3.10	17.14	0.30
Oct. 6	3.00	3.97	4.50	12.20	0.31
Nov. 10	3.65	4.20	5.70	7.50	0.30

Table II

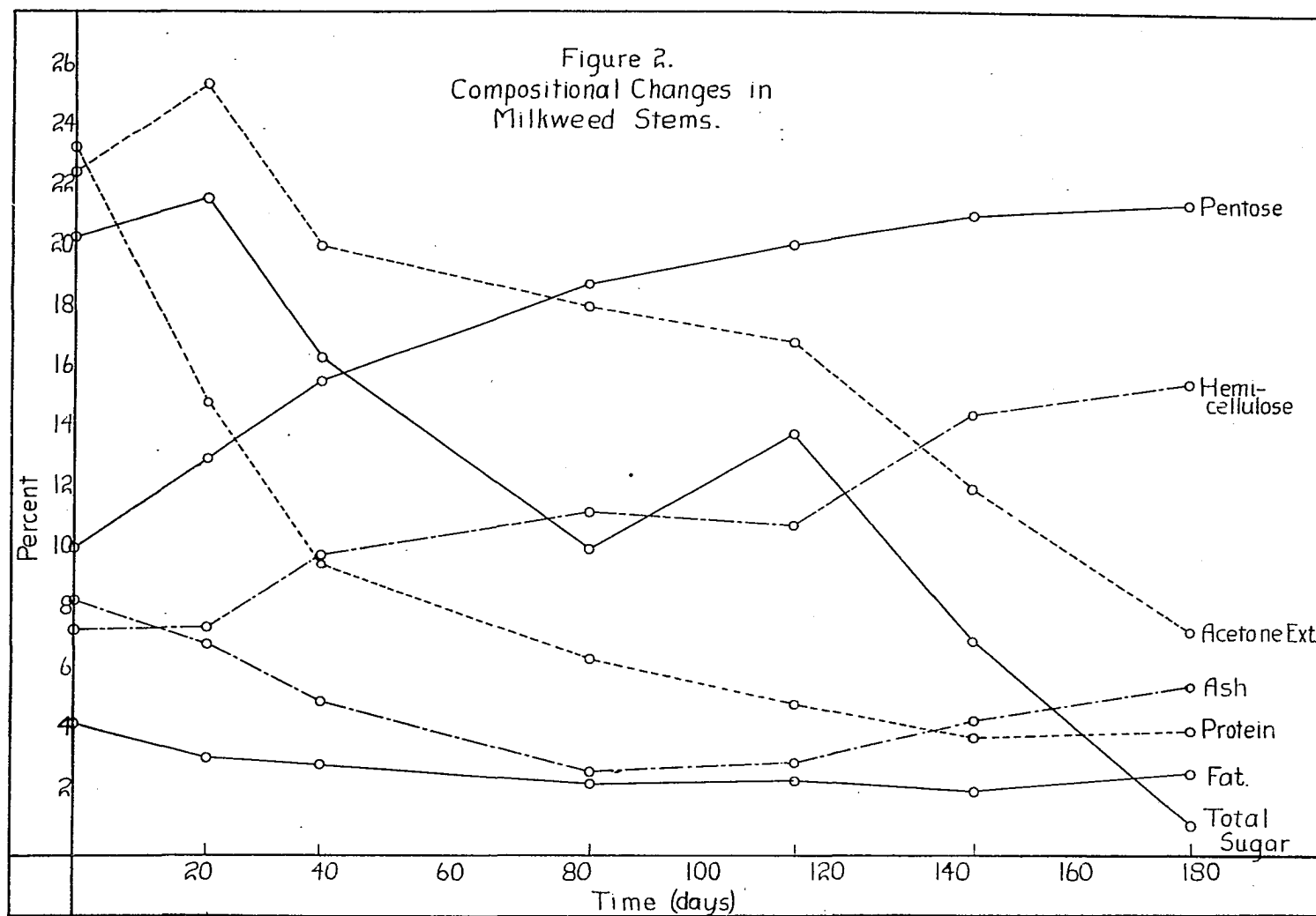
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Benzene Extract	Reducing Sugar	Total Sugar	Starch & Dextrin	Acid Hydrolyzable	Fat	Pentose
0.49	4.83	15.10	0.95	5.48	5.75	9.52
0.60	5.84	13.02	1.75	6.52	6.30	10.53
0.81	5.28	11.28	0.95	7.40	6.40	12.13
1.50	2.17	8.48	0.00	6.50	8.18	10.55
2.55	1.95	8.50	1.08	5.48	10.45	10.02
2.85	0.68	3.70	1.07	7.76	11.35	12.03
0.82	1.80	3.74	2.49	8.28	8.00	10.73

Table III

0.30	15.68	20.56	1.27	7.49	4.40	10.02
0.27	15.08	21.88	0.92	7.60	3.25	13.20
0.47	9.68	16.48	1.40	10.00	3.05	15.82
0.40	6.88	10.20	0.32	11.48	2.40	19.06
0.30	8.25	14.08	0.75	11.04	2.50	20.33
0.31	5.02	7.13	1.30	14.72	2.15	21.25
0.30	0.88	1.00	0.00	15.76	2.75	21.64

* No iodine reaction for starch. The small amount of reducing substances present here represent dextrans and H₂O soluble pentosans.



represented by the sampling of November 10 shows that a killing frost destroys over four-fifths of the rubber normally present in the leaf. This fact is again illustrated in the following:- 2.53 per cent present five days after and 0.50 per cent present two weeks following death by freezing.

The composition of the stems as represented in Table 3 and Figure 2, indicates a high initial content of nitrogen, reducing, and total sugars. Increase in maturity is accompanied by a decrease of 83 per cent nitrogen, together with a loss of 65 per cent of the total sugars. Normal development in the case of the stems, however, is not accompanied by such decided changes in ash, fat and rubber content as was found in the leaf. Pentosan and hemicelluloses increase with stem development. Death by freezing, as shown in the sampling of November 10, causes a decided loss in the acetone extract, reducing and total sugars. The water extraction and negative iodine test for starch leads to the conclusion that starch does not exist as a reserve food material in the stems or in the leaves. It will be seen from Figure 2 that pentose and hemicellulose remain the only constituents possessing a positive slope, indicating that maturity in the stem is associated with the deposition of these colloidal carbohydrates.

The results of chemical analyses on the root tissue at monthly intervals during the year are shown in Table 4 and Figures 3 and 4. The fat, ash and low acetone extract remain

Table IV

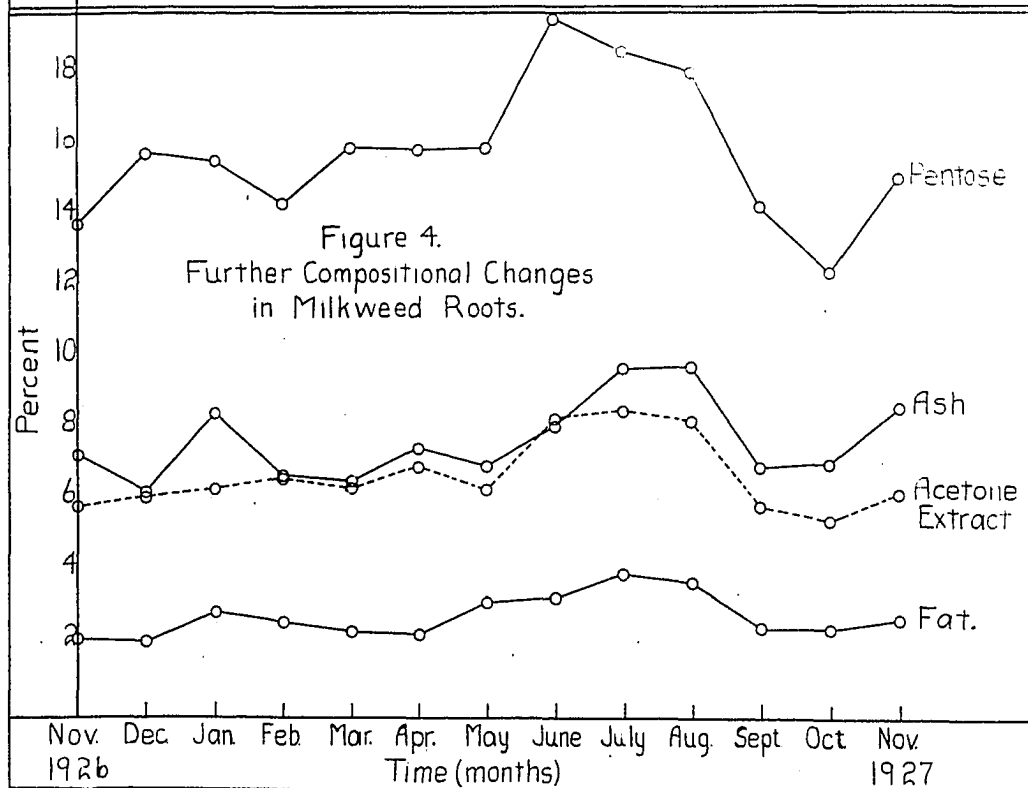
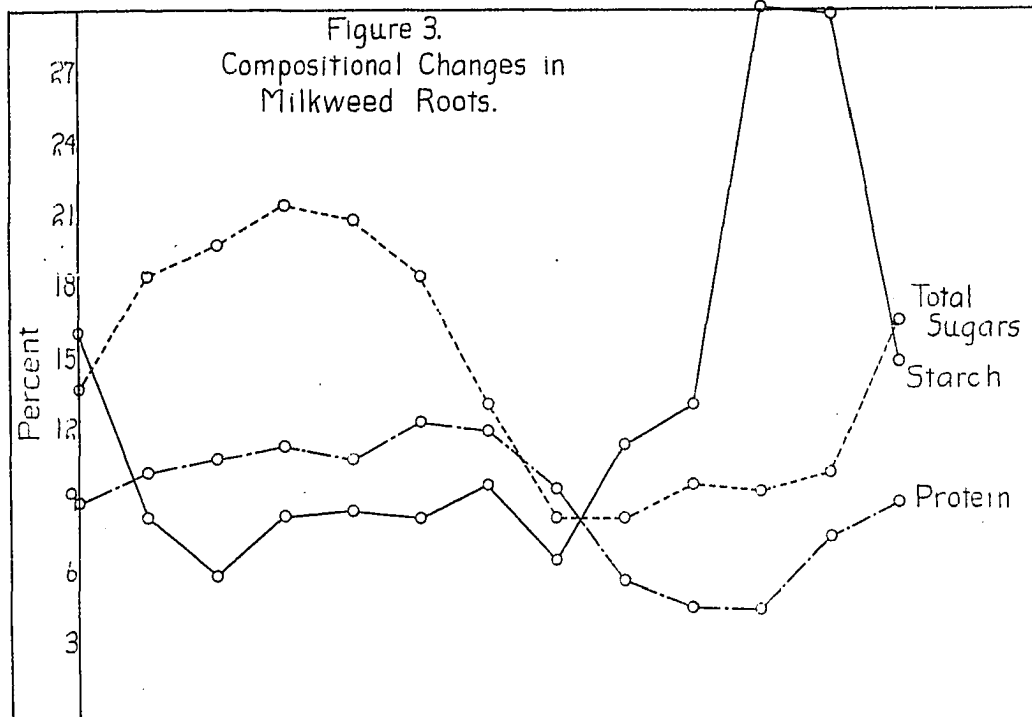
SHOWING COMPOSITIONAL CHANGES IN MILKWEED ROOTS

Sample	Moisture	Ash	Total Nitrogen as Protein	Acetone Extract	Benzene Extract	Fat
Nov. 3	4.10	7.35	9.18	5.90	0.00	2.20
Dec. 1	3.60	6.30	10.50	6.15	0.00	2.10
Jan. 8	2.80	8.50	11.17	6.40	0.00	2.95
Feb. 10	4.00	6.78	11.59	6.70	0.00	2.68
Mar. 12	4.00	6.60	11.17	6.40	0.00	2.40
Apr. 10	4.00	7.50	12.77	7.00	0.00	2.33
May 4	3.40	7.00	12.34	6.35	0.00	3.22
June 5	3.00	8.18	9.88	8.35	0.00	3.35
July 1	3.30	9.80	5.90	8.60	0.00	4.00
Aug. 5	2.60	9.85	4.81	8.30	0.00	3.75
Sept. 7	3.00	7.00	4.72	5.90	0.00	2.50
Oct. 7	4.30	7.12	7.80	5.55	0.00	2.50
Nov. 10	2.40	8.70	9.21	6.30	0.00	2.80

Table IV

ROOTS

Benzene Extract	Fat	Reducing Sugar	Total Sugar	Starch & Dextrin	Acid Hydrolyzable	Pentose
0.00	2.20	0.52	14.08	16.38	9.26	13.84
0.00	2.10	0.50	18.72	8.56	9.00	15.85
0.00	2.95	1.40	19.06	6.19	8.90	15.65
0.00	2.68	1.30	21.84	8.71	8.91	14.43
0.00	2.40	1.45	21.12	8.97	10.12	16.00
0.00	2.33	2.30	18.72	8.58	9.52	15.95
0.00	3.22	1.41	13.40	10.00	8.64	16.00
0.00	3.35	3.20	8.60	6.80	9.00	19.65
0.00	4.00	3.00	8.59	11.70	9.52	18.70
0.00	3.75	3.93	10.04	13.40	8.84	18.16
0.00	2.50	2.12	9.67	30.56	8.70	14.34
0.00	2.50	0.88	10.56	29.44	8.00	12.50
0.00	2.80	0.80	17.28	15.20	8.60	15.15



fairly constant with a slight increase in each through the months of July and August. There appears to be no determinable rubber present in the roots of the common milkweed plant during any stage in their development. A small deposition of pentosan material occurs during the early summer months, while acid hydrolyzable values remain constant. It is in the root that one first encounters the presence of starch. This fact appears rather significant because in neither the leaf nor the stem, where rubber is present, does one find this reserve carbohydrate. During the winter and spring season, the root contains little starch; great activity is seen, however, in the deposition of this material during the summer and early fall months. This period is represented by a stage of great metabolic activity in the green portion of the plant. During this time flower formation and fertilization have taken place.

The total sugars, however, vary inversely with starch deposition. A large amount of soluble sugars is present during the winter months, followed by a loss during the growth cycle of the summer period. Nitrogen as well as sugar in the root, remains high during winter and drops to an exceedingly low level during July and August, corresponding to the period of protein deposition in the seed. Figure 3 shows the interrelationship between total sugars, starch and nitrogen. In both leaves and stems, nitrogen and soluble carbohydrates appear to be closely associated in amount and time of utilization. It is strikingly shown in the above figure that upon June 5 these active food

constituents approach a common level. This period should represent the opportune time to carry out a successful eradication program. The above relationship is represented in the green portion of the plant by the early blossom stage.

Composition of the Latex

The laticiferous system of the common milkweed, is unlike the articulated arrangement found in the Papaveraceae, Chicoriaceae and Hevea. It is composed of nonarticulated latex-cells. Hence in rupturing the surface of this plant, only a small amount of the white sticky latex is obtained. The total amount of the contents thus secured must depend upon the number of individual latex cells ruptured. It became an exceedingly tedious task to collect sufficient latex for even a chemical analysis. The most feasible method of collection entailed the use of a small test tube suction trap. A leaf or portion of the stem was ruptured at several places, with the appearance of a drop or two of latex. The latter was sucked into the trap and the rupturing process repeated. Milkweed latex coagulates readily when in contact with the air. The collection of about twenty cubic centimeters of latex entailed the use of approximately thirty plants and some three hours labor. The chemical composition of milkweed latex as compared with that of a four year old India Rubber Tree (Hevea brasiliensis L.) is shown in Table 5.

Table 5

MILKWEED		INDIA RUBBER*
		TREE (Hevea)
72.00%	Moisture	70.00%
1.40%	Ash	0.26%
4.00%	Total Sugars	0.79%
23.00%	Resins	1.22%
3.34%	Rubber	27.07%
0.46%	Total Nitrogen	0.24%

It can easily be seen from this table that milkweed latex offers a much inferior source of rubber. The moisture and total nitrogen content of the latex from both sources approach a common level. It is in the distribution of rubber and resins wherein lie the most remarkable compositional differences. Milkweed latex contains over twenty times the amount of resinous material and only one eighth the amount of rubber found in the Hevea exudate. Ash and sugar values are from five to six times greater in the case of the milkweed latex. From the above analysis, it becomes self-evident that economic utilization of milkweed as a source of rubber would necessitate a decided rearrangement in resin-rubber content. Whether this can be accomplished, by cultural and plant breeding methods, remain at present an open question.

* Beadle, C. and Stevens, H. Some Analyses of Hevea Latex. In the Analyst, Vol. 36; 6-9, 1911.

Chemical Study of the Plant Products.

The value of any plant, obviously, is dependent upon the adaption of its various parts to some useful application. In the case of the milkweed, the attention must be focused upon the possible products associated with the seed, with the stem tissue, and with the coma.

Milkweed seeds contain a large amount of nitrogen and fat. The quantity of these constituents vary somewhat with the environment of the plant. Analyses of the seeds from the experimental plot as compared to native grown, show the former to contain about three per cent more of the above compounds. In Table 6 will be found the analyses of the 1927 crop of milkweed seed, together with a comparison of the seeds of several other crop plants.

Table 6

Analyses of Various Plant Seeds

: Name of Plant :	% Protein :	% Fiber :	% Fat :	% Ash :	
: Milkweed :	37.53 :	11.50 :	21.20 :	4.1 :	(CaO .40% (MgO .63 (P ₂ O ₅ 1.33
: Cotton seed* :	19.50 :	22.00 :	19.00 :	4.6 :	(CaO .12 (MgO .32 (P ₂ O ₅ .53
: Flax Seed* :	22.00 :	7.10 :	33.00 :	4.3 :	(CaO .24 (MgO .30 (P ₂ O ₅ .51
: Soy Bean* :	36.00 :	4.00 :	17.00 :	5.3 :	

* Henry, W. A. and Morrison, F. B. Feeds and Feeding. ed. 18, p. 709. Madison, Wisc. 1923.

It is evident that from a compositional point of view, milkweed shares a like honor with several of our crop plants. The important inorganic ash constituents are considerably higher in the case of milkweed seed.

Since almost one-half of the milkweed seed meal is composed of nitrogenous material, a preliminary partition of some of the more important fractions was undertaken at this time. The fat extracted meal used in the following partition contained 7.42 per cent nitrogen, or 46.4 per cent crude protein. Table 7 shows the distribution of some of the nitrogenous material in the seed.

Table 7
Partition of Certain Nitrogenous Fractions
of Milkweed Seed.

:	:H ₂ O Soluble	:0.3% NaOH in 60%:	:
:	: Fraction	: alc. fraction	: Whole Meal
:% Total N	:	:	:
:Extracted	: 48.70	: 34.00	: 82.70
:% Heat Coag.	:	:	:
:N (Albumins)	: 51.20	: 51.40	: 42.50
:% P. W. A. N	:	:	:
: (Diamino)	: 28.50	: 29.30	: 23.00
:% Alpha amino:	:	:	:
: Acid N	: 5.30	: 6.70	: 4.90
:% Recovery of:	:	:	:
:total extd.	: 85.50	: 87.40	: 70.40

It can be seen from Table 7 that almost one-half of the total nitrogen present in milkweed seed is extractable by water. One-half of the water-soluble fraction is composed of proteins precipitable by heat, while slightly over one-quarter

of this fraction is composed of peptones and diamino acids. Alcoholic-alkali removes 66 per cent of the nitrogen remaining in the water extracted residue, or 34 per cent of the total nitrogen present in the meal. The percentage of nitrogen recovery in the various forms, follows closely that found in the water-soluble extraction. This fact would tend to indicate the presence of but one general type of protein in the milkweed seed, differing possibly only in extractive solubility or availability. Table 7 indicates that the protein of this seed is composed of about 42 per cent heat coagulable material, 25 per cent peptones and diamino acids, with free alpha amino acids comprising about 5 per cent of the nitrogenous constituents of the seed. The nutritional value of milkweed proteins as compared to those from cottonseed, linseed and soy bean is being studied at present and will be reported separately at a later date.

Oil:- Milkweed seed upon extraction or expression yields 21 per cent of a yellow oil bearing the characteristic odor of the plant. A refinement procedure was applied to a portion of this oil consisting of heat treatment to 51° C., followed by agitation with a requisite amount of NaOH and subsequent filtration. The filtered oil was then washed with water until the last traces of alkali had been removed. The result was the production of a clear golden yellow-product which could be graded upon the open market as a good grade of Summer Yellow Oil. A sample of this oil had the following physical and chemical properties:-

Specific Gravity - - - - - .9230 at 15° C.

Index of Refraction - - - 1.4714 at 30° C.

Reichert Meissl Number - - 0.50

Polenski Number - - - - - 0.30

Saponification Number - - -193.6

Acetyl Number - - - - - 11.7

Iodine (Hanus) Number - - -128.6

Free Fatty Acids in Crude Oil

(as Oleic) - - - - 4%

These constants would classify milkweed oil as a semi-drying oil, along with those of cottonseed, sunflower and soy bean. It is also possible, by agitation with Fuller's Earth, to so bleach this oil that a clear, colorless product can be obtained, possessing the appearance and consistency of the various edible plant oils now used in cooking.

Seed Fibers:- The fertilized ovary of the milkweed flower, during maturation of the plant, gives rise to a characteristic structure called a pod. Tightly compressed around the placenta within the fruit are found the silvery white seed hairs with a length from 12 to 30 millimeters and in diameter from .02 to .05 millimeters. Upon rupture the coma is noticed to be entirely encased by the seed. Each fiber comprises a single cell, usually slightly distended at the base. The fibers are straight, brittle, high in lignin and ash. From the photomicrograph, Plate 6, it appears that the fibers lack twist and have con-

spicuous lumina and thin cell walls.

The reports which have been published tend to show that the milkweed fibers are unsuited for textile utilization. (24) Schorger found milkweed coma high in lignin and unsuited for paper making. There is still the possibility that these fibers may be used to an advantage in the wadding and upholstering industry. The cooperation of several large bedding and upholstering manufacturers was sought and obtained in this connection. Generous samples of ginned milkweed seed fibers were offered and accepted for experimentation. The result of efforts in this direction has convinced the author that the above material offers certain restricted commercial possibilities.

The extreme brittleness of the fiber appears to be the chief difficulty encountered in the successful utilization of milkweed coma by the upholstering industries. During processing, however, a large amount of the fibers are broken, forming the so-called "dust." Cotton also liberates some of this dust, but it is possible here to "pick" and blow the dust from the cotton before utilization. When used without a tight inner cover, milkweed upholstered material appears to continually shed some dust or broken fibers. This property would tend to hinder its applicability for ordinary upholstering purposes. However, since this vegetable fiber is exceedingly light, fluffy, and quite resilient, it lends itself admirably to use in Fabricoid upholstered articles. Suggestions from several commercial firms

indicate that milkweed floss can readily be blown and would yield a product superior to the ordinary cotton linters now used extensively in Fabricoid upholstering. There are many cheaper mattresses produced at present from the blown cotton dust and linters;- these are known under the name of "blow mattresses." Information has been received that blown milkweed floss produces a far better pad than does blown cotton. Since both mattresses and Fabricoid upholstered material, especially in the automobile industry, are used under varying humidities, the absorption of moisture becomes an important property of the fiber. Milkweed floss withstands a heavy humidity better than does cotton. The former will fluff up quickly and almost to natural condition after immersion in water, while cotton does not possess this property to any marked degree.

Asclepias floss possesses a much greater buoyancy than does cotton; it compares favorably with kapok in this respect. Comparative submersion tests of cotton and milkweed floss were made by taking equal weights of uncompacted fiber, covering each with a weight-suspended canopy of cheesecloth, thus permitting every fiber sample to attain its optimum volume for each submersion weight. Submersion took place in the case of cotton by applying a twenty-five gram weight per gram of fiber; milkweed fibers required a fifty-four gram weight per gram of floss for submersion. Asclepias fibers supported thirty-seven

times their own weight for sixteen hours; thirty times their own weight for one hundred sixty-eight hours, requiring twenty additional grams to induce submersion at the close of this period. Ten grams of the floss again supported twenty-six times its own weight for one hundred sixty-eight hours, requiring an additional one hundred ninety grams for complete submersion. Since the above buoyancy values approach those of Kapok it would appear that milkweed floss could also be utilized along our sea coasts as a filler for life buoys and preservers.

Wall Board Pulp:- Milkweed stems are hard, woody and hollow; they also contain a natural mucilaginous binding material. While it is true that there are many sources of wall board material in the various cellulose wastes of commerce, it was thought advisable to include in this report some preliminary figures on possible yields from the milkweed stems accumulated in this general investigation. The composition of the annual stem growth of this plant is such that a drastic preliminary cook prior to pulping is not imperative. 400 grams of milkweed stems, broken into one-half inch pieces, were subjected to a 10 per cent caustic soda cook for eight hours at 20 pounds pressure. The washed, alkali-free, pressure cooked material was beaten to a coarse pulp in a small paper beater, placed into a hand mold, compressed, and dried. The resultant board was dark in color, bone-hard, and warped badly upon drying. The low yield and general properties of the finished board indicated

that 10 per cent caustic soda for eight hours at 20 pounds pressure was too drastic a treatment for these stems.

Milkweed stems subjected to a 10 per cent lime cook for eight hours at 20 pounds pressure, and receiving the subsequent manipulation noted in the soda process, yielded a superior product, that showed a minimum of discolor, warp, and shrink. The yield of finished material per dry weight of the stem amounted to 82.5 per cent in the lime cook process. Subjection of the hydrated stems directly to the action of the beater, minus prior chemical processing, resulted in a high yield of 88 per cent of board material. In the latter case, however, the beaten pulp remained somewhat coarser, and the resultant board was not as firm or smooth textured as in the lime cooked material. These preliminary paper pulp investigations show that the long, fibrous, woody, stems of the milkweed offer a rich source of paper and wall-board material, should the production of the plant ever attain a commercial success.

Bast Fibers:- Just beneath the bark and along the outer surface of the woody collenchyma tissue of the milkweed stem, can be found a layer of numerous strings or strands of fibrovascular bundles containing bast fibers. These structures are found extending the entire length of the plant. Like flax, hemp or jute, these fibers may be separated from the bark and woody portions of the stem.

Air-dried stems grown on the experimental plot, and des-

iccated at room temperature, served as a source for the following bast fiber investigations. Mechanical separation of the fibers can be accomplished by a simple scutching of the untreated stems. The resultant strands, however, remain hard, brittle and encased in a dried mucilaginous gum. Since ammonium oxalate extraction has been used for the quantitative estimation (26) of pectin, there remained the possibility that the above fibers might be freed from their incrustated material by subsequent extraction with this reagent. Digestion of this material in a hot 5 per cent ammonium oxalate solution removed most of the foreign material, leaving the fibers soft and white. This fact would indicate that the bast fibers of the milkweed are associated with a certain amount of pectinaceous material.

The average yield of soft, bark-free fiber of the milkweed amounts to 10 per cent of the dry weight of the stem. The bast fibers contain about one-third the amount of ash material as compared to those from the seed. The ash content of the bast amounts to 0.3 per cent while those of the seed contain 1.02 per cent. The former vary in length from 15 to 25 millimeters and from 0.025 to 0.050 millimeters in diameter. The general structure of the bast fibers is shown in Plate 7. They are soft, pliable, almost white in color, much finer in texture than hemp and resemble flax very closely in appearance. Tensile strength measurements, of milkweed bast and seed fibers together with those from several other plant sources, were made by determining

the weight in grams necessary to break the individual fibers. The tensile strength of vegetable fibers vary considerably due to moisture content, physical form, and thickness. Data giving tensile strengths of the various fibers, including milkweed, are submitted in Table 8.

Table 8

Tensile Strength of Various Fibers

Fiber	Breaking Strength in Grams	Tensile Strength, Kilograms per sq. millimeter
Cotton	7	34.27
Linen	16	36.40
Artificial Silk	10	37.00
Bog Cotton	4.7	30.40
Milkweed Seed Fiber	4.2	30.00
Manilla Hemp	31.	52.00
Milkweed Bast Fiber	20.	40.80

The bast fibers of the milkweed are stronger than those of flax but not as strong as hemp. It would appear that milkweed bast fibers might be utilized as a textile or cordage material. In order to investigate this possibility, four sheaves of milkweed stems, as shown in Plate 4, were placed in a slate tank 3' x 6' x 18" and allowed to rett while submerged in distilled water. During the retting process a slight acidity as well as a distinct butyric acid odor could be detected.

Decomposition at the end of 10 days, had progressed to such a stage whereby the bast fibers together with bark could readily be stripped from the woody portion of the stem. The retting tank was drained, also the retted material washed with water and allowed to dry. Separation of the fibers from the dry, retted, stems was easily accomplished by beating a handful of the latter, and allowing the woody collenchyma tissue to drop away from the retained bast fibers.

Samples of tank retted bast fibers were offered to several commercial cordage and textile manufacturing establishments for a report as to the value of this material in their respective industries. Their reports show that milkweed bast fibers can not be used to an advantage in the industry and would have little competitive value against such fibers as hemp, cotton and flax. As a source for rope and twine, these fibers lack the tensile strength necessary to withstand successful competition against such fibers as hemp and ramie. It is to be appreciated, however, that the possibilities of this phase of the problem have not been entirely exhausted. An attempt will again be made to obtain data upon Asclepias fibers from stems retted by subject-ion to natural weathering processes.

DISCUSSION

The results of this study may serve to focus attention toward numerous latent possibilities inherent in many of our uncultivated plants. This phase of plant investigation offers its students a wide field of endeavor, and should aid in that difficult task of removing possible prejudices against the introduction of new plant genera as potential crops.

Propagation, obviously, exerts a major influence in the successful cultivation of any plant. In the distribution of perennial families, such as the Asclepiadaceae, vegetative reproduction and seed germination play an important role. The former method frequently offers the plant breeder a more rapid means of establishing his crop. In the milkweed, however, reproduction by root cuttings was dependent upon the elimination of a well defined rest period in the root tissue. During natural propagation of this plant, a large amount of new growth, undoubtedly is obtained by vegetative means. Nevertheless, the experimental applicability of this type of reproduction did not lend itself to successful manipulation in the greenhouse.

The establishment of new milkweed plants over great distances is accomplished by means of seed dissemination. It was found in this study that milkweed seed must pass through an after ripening period of several months before successful germination can be attained. The various methods designed to induce germination, exerted no decided effect upon seeds collected

shortly after maturity. Evidently changes in temperature, such as freezing and thawing, greatly aid in the germination of milkweed seeds; since seeds allowed to remain in the pod over winter showed a high percentage of viability. Seed which had been allowed to pass through an after ripening period of about three months, showed a marked germinational response to scarification. Almost an equal viability was attained by either chemical or mechanical mutilation of the testa. Thus it can be seen that successful propagation of the milkweed plant from seed may be accomplished in much the same manner as are our perennial alfalfa and biennial clover crops. (17)

In the cultivation of the milkweed, several annual strains were discovered. This fact should interest the geneticist and plant breeder since it offers a possible means of developing new and valuable strains within the species. It should be remembered that in the development and production of our sugar beet of today, many years of careful scientific effort were required. Even in the India rubber plantations, many years of experimental breeding were mandatory to the enjoyment of present day attainments. Since this study represents the first attempt to grow the milkweed plant under cultivation, it remains possible only to indicate and stress its various possibilities in the light of past experimentation upon such plants as the sweet potato, soy bean and sugar beet. (17)

Harvest of the milkweed differs from that for cotton, since most of the seed and coma would be lost unless it were collected

before the pods opened. In regard to Asclepias floss, fiber brittleness appears to hinder its mechanical manipulation to a greater extent than in the case of cotton. However, the milkweed seeds are borne upon the outer surface of the seed fiber, and are not embedded therein as in cotton; they, therefore, offer less resistance to ginning. It was found that an ordinary cotton gin could be adapted to seed separation in the milkweed. The results reported in this investigation show that only approximately one-fourth of the theoretical yield was obtained. It must be recalled, however, that these yields are based upon merely the first year's crop of a plant that has been grown under native conditions for a long time. Quite likely the second year's production will be greater than the first, especially if due consideration is given to the mitigation of unnecessary competitive growth within the cultivated area. In other words, over crowding of the plants within the row should be eliminated. Observations have shown that the milkweed propagates itself to such an extent that severe thinning out of the young growth is frequently necessary.

The question of food elaboration and translocation becomes of prime importance in the case of perennial plants. In such types, the plant must not only synthesize and store certain food reserves in the seed, but also translocate large amounts of reserve energy into the root for subsequent vegetative reproduction. ⁽⁴⁾ Curtis has reported that food materials, once

stored in the roots, are used solely for root development.

Analyses of the milkweed show that this plant exerts a decided demand upon the inorganic soil constituents. The leaf tissue, particularly, indicates that a large deposition of ash materials occur with maturity. It is apparent from the analytical data that the soluble sugars and protein appear in large amounts, in stem and leaf tissue, during early growth. However, with the inception of seed deposition, these food materials gradually diminish and are translocated to the storage organs. It is interesting to note that starch is first encountered in the root of the milkweed, where it is stored during the late summer and fall, only to be converted into soluble sugars during the winter. Does the accumulation and conversion of this material serve to make the plant particularly hardy as to severe winter killing conditions?

Freezing exerts a decidedly destructive action upon the rubber content of the latex; does this fact hold true for all laticiferous plants? How does a lowering of the temperature cause an apparent destruction of the rubber molecule? Analyses show that resin and gums are also destroyed by frost. Evidently the seat of rubber formation is closely allied with the photosynthetic processes in the leaf, since practically all of this hydrocarbon is localized within the tissues of the milkweed leaf. The amount of rubber in this region was found to increase with plant maturity. Evidently the analyses of Fox (7)

were based upon mature plants, since the present study indicates that the young plants contain less than one per cent of rubber in their leaves. When compared to Hevea, the milkweed latex is found to remain an inadequate source of rubber. The presence of such large amounts of resinous gums, and ash constituents in milkweed latex, offers strong evidence that the controlling mechanism in the synthesis and deposition of this material must be decidedly different from that of our tropical laticiferous plants. It should again be recalled that starch and rubber do not co-exist within the chlorophyll bearing tissue of the milkweed. Chemical analyses indicate that with an increase of rubber in the leaf, there also appears a deposition of starch in the root.

(21)

The work of Parkin has shown that starch is absent from the green portions of several plants. ⁽⁵⁾ Davis, Daish, and Sawyer have also indicated that the leaves of the mangold Beta vulgaris L. contain no starch. Evidently starch is not a direct product of photosynthesis in this study, since none could be identified in the green portion of the milkweed. This would indicate then that the soluble photosynthetic products are first translocated to the roots and there converted into starch. It was found that this process of synthesis, translocation, and conversion increased during the latter portion of the summer.

As shown in the present study, the various plant parts possess constituents worthy of more serious consideration. The

seed offers a rich source of oil and nitrogenous material. From this study, it becomes evident that milkweed oil possesses constants and properties comparable to our better known plant oils. Almost one-half of the fat extracted seed meal is made up of protein material. The value of this as a stock food, however, will depend upon its amino acid content, and supplementary feeding value. No effort has been made in this report to determine whether or not milkweed seeds contain a toxic principle analogous to Gossypol in the cotton. Preliminary feeding tests indicate, however, the absence of such a constituent.

The physical and chemical properties of the milkweed floss are such that its utilization, as compared to cotton, would be greatly restricted. Fiber brittleness and lack of twist will bar its use in the textile industry. As a filler for artificial leather upholstered commodities and for certain types of cheaper mattresses it appears to surpass linter cotton. Due to its characteristic buoyancy, however, it offers a new source of material wherever this property is mandatory. It is possible that a variety of milkweed plants possessing a more resilient, stronger and less brittle fiber may be developed. Whether this could be done in quantities that would permit competition with cotton and kapok is, however, another problem.

Any plant, in order to acquire the status of a profitable crop plant, must either in itself or through its by-products, successfully supply some specific economic demand. The income

from the seed products will aid, but not warrant cultivation of the milkweed plant. The coma and bast fibers must in turn also meet the approval of specific commercial application.

SUMMARY

The common milkweed may be propagated by root as well as of the seed by seed. Scarification was found to be the most effective means of securing a high percentage of germination. This plant has been successfully grown under cultivated conditions.

There was a gradual increase in rubber content from 0.5 to 3.5 per cent with plant maturity. A killing frost destroyed over 80 per cent of the rubber present in the plant. No starch was found in the green portion of the common milkweed.

Five annual strains of perennial milkweed plants were found in the experimental plot. Self-fertilization produced sterility.

Successful harvest necessitated pod collection just prior to their rupture. Seed separation was accomplished by use of an ordinary hand cotton gin.

Milkweed seeds weigh from 20 to 25 pounds per bushel. The yield of 0.6 bushel of seed, five pounds of coma and 90 pounds of air dry stems per 1/20 acre represented about one-fourth of the possible theoretical yield of 48 bushels of seed, 400 pounds seed fiber and 3 tons of stems per acre. Low experimental yields were due largely to excessive drought, crowding, and competitive growth relations within the plot.

The seeds contained 37.5 per cent crude protein, 21 per cent oil, 11 per cent fiber, and 4 per cent ash. Nearly one-half of the seed protein was soluble in water; 35 per cent of the remainder was soluble in alcoholic-alkali. The nitrogenous seed con-

stituents were composed of 5 per cent alpha amino acids, 23 per cent diamino acids and peptones, with 42 per cent of the remaining nitrogen being represented by heat coagulable albumins.

Determined constants classify milkweed oil as a semi-drying oil. The crude oil contained 4 per cent free fatty acids expressed as oleic.

The leaf lost from 70 to 80 per cent of its carbohydrate and nitrogen reserves during maturity; while fat, ash and rubber accumulated. In the stem, maturity was associated with the deposition of reserve colloidal carbohydrates such as pentosans and hemicelluloses; the carbohydrate-nitrogen losses in the stem emulated those of the leaf. Food reserves in the root were at their lowest ebb during the fore part of June. During flower fertilization and seed formation, the starch content of the root increase enormously, while sugars and nitrogen attained their lowest level.

Milkweed seed fibers are straight, brittle, high in ash and lignin, thereby not lending themselves well to ordinary upholstery purposes. They can be used to an advantage in Fabricoid wadding and in the cheaper blown mattresses. The buoyancy of these fibers compares well with that of kapok and could be utilized where this property is demanded.

Tensile strength measurements of the bast fibers show them to be stronger than flax, but not as strong as hemp. Bast fiber yields approximated 10 per cent of the stem dry weight. They

appear to lack the tensile strength necessary to successfully compete against such cordage fibers as hemp and ramie. An excellent quality and yield of cellulose board can be produced from the stems.

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Plate 1. Milkweed plant 180 days old showing
root development, seed planted May 14,
roots dug Nov. 10, 1926, Ames, Iowa.



Plate 2. Milkweed plants dug May 4, 1927 showing growth of new plants from one year old roots.

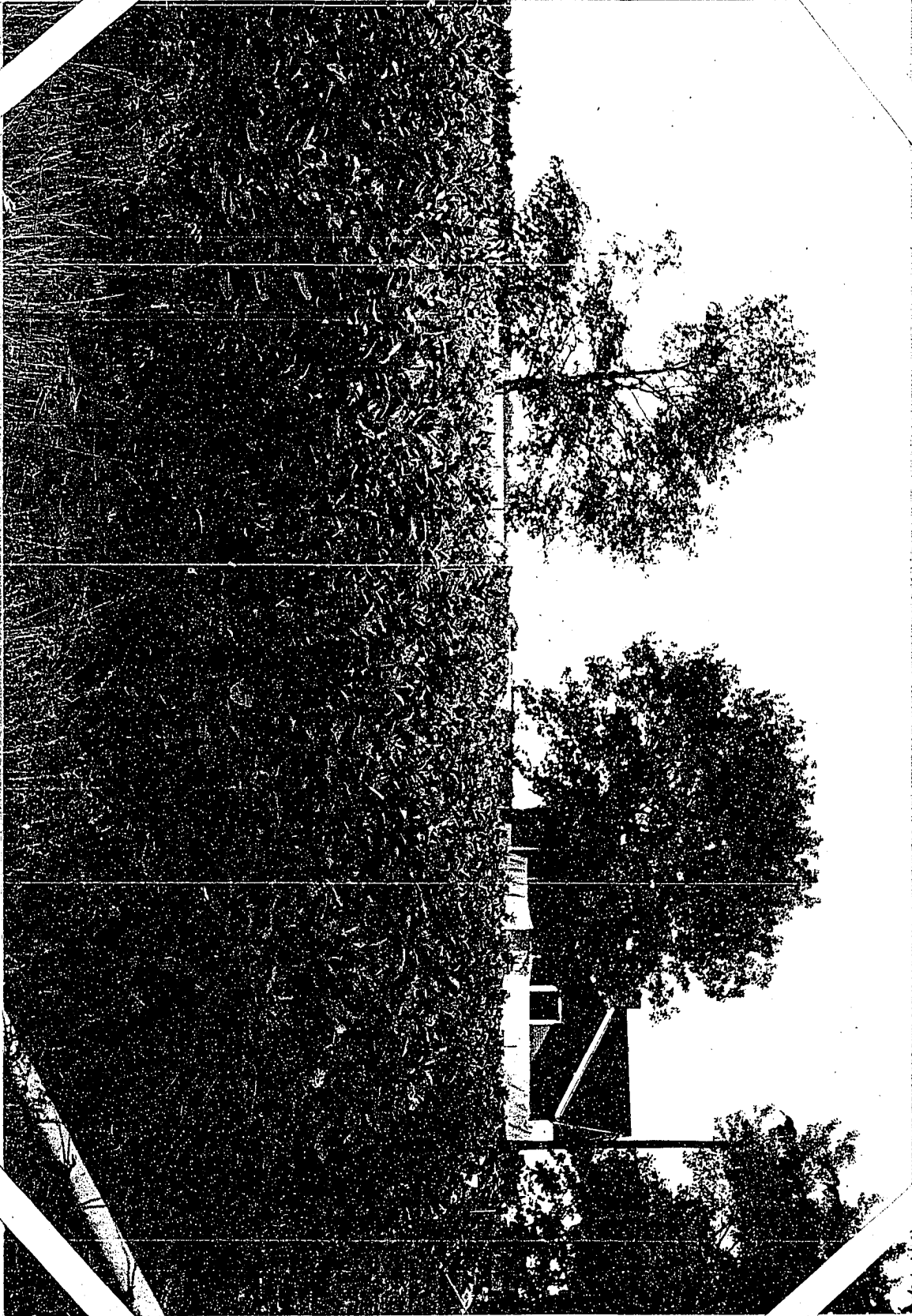


Plate 3. Experimental milkweed plot. Blossom stage. July 14, 1927, Ames, Iowa.

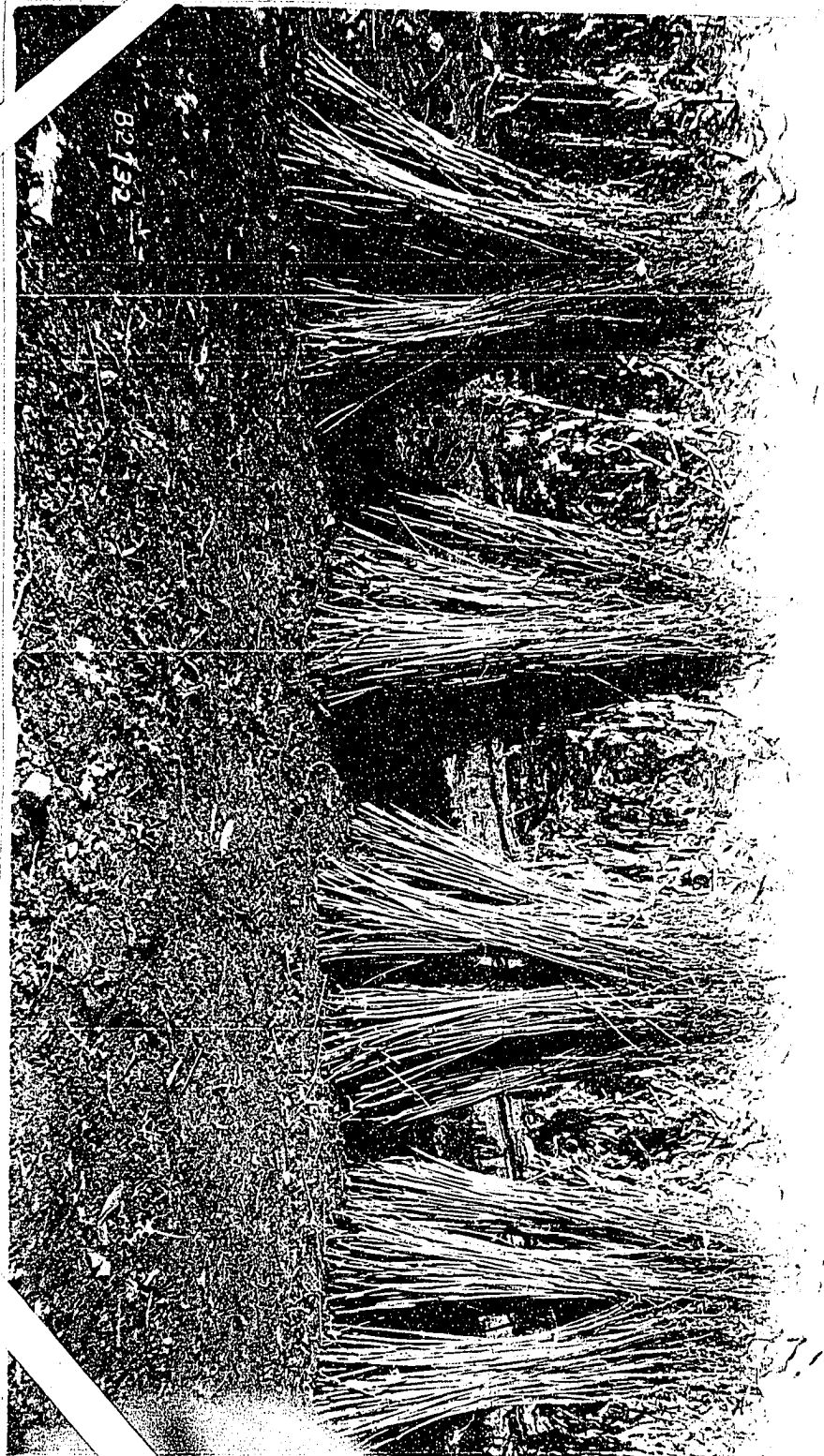


Plate 4. Yield of milkweed stems and method
of harvesting. Stems cut Oct. 14,
1927, Ames, Iowa.



Plate 5. Effect of experimental conditions upon yield
A. Experimental plot
B. Native grown

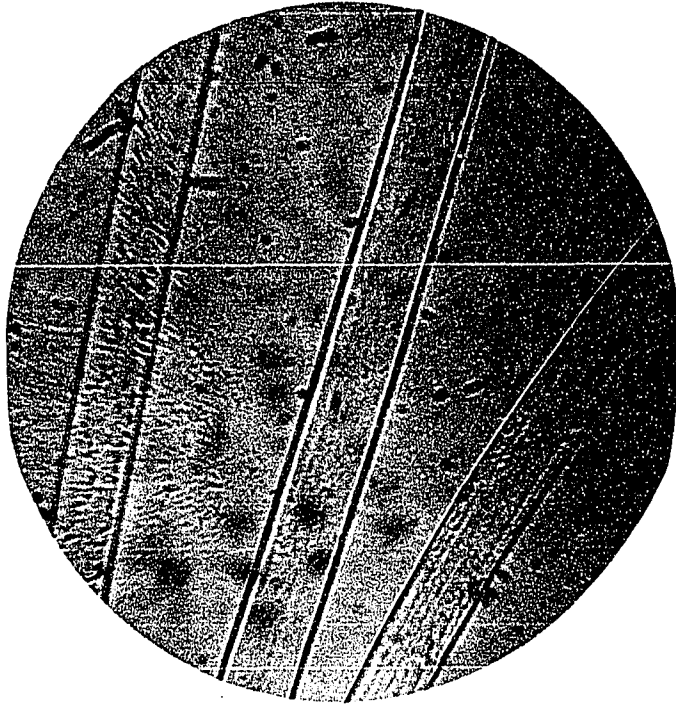


Plate 6. Photomicrograph of milkweed seed
fibers, showing large lumen and
thin cell wall.

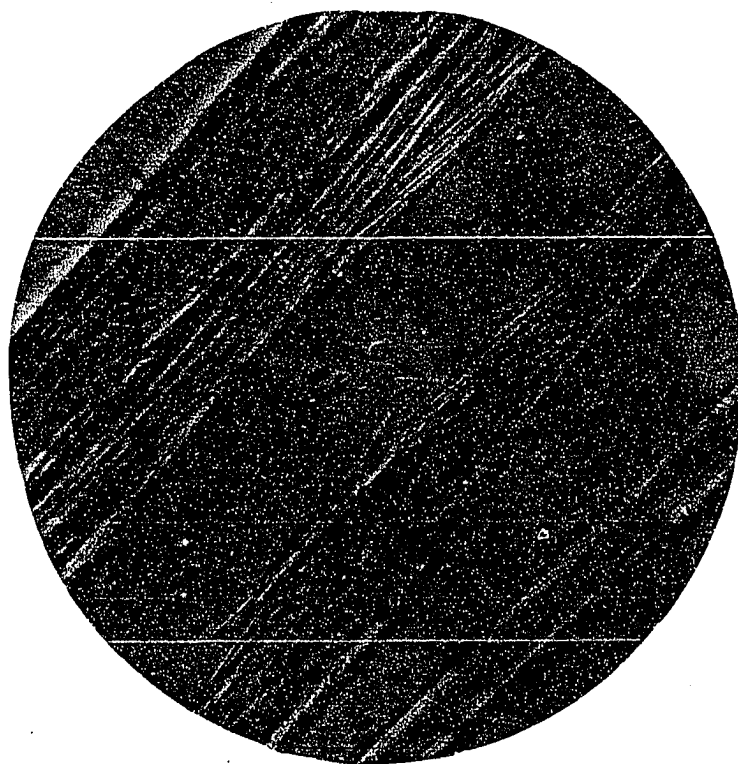


Plate 7. Photomicrograph of milkweed
bast fibers, showing narrow lumen
and protoplasmic striations.